INSTALLATION AND TEST OF A THREE - TON YORK REFRIGERATING PLANT

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ARMOUR INSTITUTE OF TECHNOLOGY

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INSTALLATION and TEST

OF A

THREE-TON YORK REFRIGERATING PLANT

A THESIS

PRESENTED BY

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L. C. Monin
Dean of Cult. Studies

G. F. Gebhardt
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PREFACE.

The Installation and Test of a Three Ton York Refrigerating Plant was conducted by the authors of this report at the Armour Institute Laboratory Building on Dearborn Street, Chicago, Ill., from September 1912 to May 1913. This installation and test was under the direct supervision of Prof. E. S. Libby of the Mechanical Department of Armour Institute of Technology. Special mention is due to the following men, who assisted in the running of the test:

Mr. L.H. Philleo,
Mr. M. D. Wald,
Mr. John Wintercorn,
Mr. E. A. Hager,
Mr. H. E. Erickson,
Mr. L. C. Meyer,
Mr. H. Himmelblau,
Mr. R. G. Bohn,
Mr. T. J. Kiene,
Mr. Wm. Smith,
Mr. A. J. Dew.

INSTALLATION AND TEST OF A THREE TON YORK REFRIGERATING PLANT.

OBJECT.

The original intention was to install all the apparatus applying to a three ton York refrigerating plant, and to make a complete test of same, determining especially the heat losses in the ammonia lines with non-insulated pipes. Due to the time required for the installation, a complete test could not be made. However a simple test consisting of the making of ice was carried out, determining the tons of ice produced per ton of coal, per indicated horse power of each cylinder, and per boiler horse power. Other general data besides that actually needed was also taken.

INSTALLATION.

The installation consisted of moving the apparatus from the old building at 3327 So. Dearborn Street to the new, in putting in the concrete foundations and trenches for the various apparatus, in setting the apparatus in place and in connecting same with suitable piping. This

order was not carried out in rotation but was followed with consistency. The plant when completed consisted of the following apparatus:

1 25 H.P. Erie Economic boiler

1 6 x 6 vertical York compressor direct connected to a 6 x6 horizontal steam engine

1 $5\frac{1}{4}$ x $3\frac{1}{2}$ x 5 Worthington pump for circulating the brine

1 Wheeler surface condenser

1 4 x 6 x 6 Marsh vacuum pump

1 Double tube ammonia condenser

1 Double tube ammonia expansion coils

2 Ammonia receivers

1 Ammonia accumulator

1 5'-3" x 14'-0" x 3'-6" freezing tank containing 35 100 pound cans for ice

1 Set of expansion coils in freezing tank

1 Oil separator in the ammonia discharge line

1 Automatic ice dump

1 automatic can filler

1 Metropolitan injector.

All apparatus for a distilled water ice system was provided but was not connected up before the test was run, so all ice was made from city water.

BOILER.

The boiler is of the return tubular type with self contained fire box, It was built by The Erie City Iron Works and rated at 25 H.P. The lower pass contains 18 4" tubes 4'-2$\frac{3}{4}$" long making 186.5 square feet of heating surface. The upper pass contains 30 3" tubes 7'-11$\frac{1}{4}$" long making 79.3 square feet of heating surface. The total heating surface is 265.8 square feet. The grate surface is 10.5 square feet. This makes the ratio of heating to grate surface 25.3. The stack is 18" inside diameter and about 35 feet in height. Water is fed to the boiler by means of an injector through a one inch pipe. The boiler is equipped with all the safety appliances demanded by the city.

ENGINE and COMPRESSOR.

The engine is a 6 x 6 horizontal steam engine of the "D" slide valve type direct connected to a 6 x 6 vertical York compressor. Both cylinders are equipped with indicator cocks. The compressor was designed to operate with zero clearance and for that reason is provided with a false head. In case a slug of liquid ammonia or any other solid matter should enter the cylinder this head, which is held down by a heavy car spring, will raise and thus prevent severe damage to the machine. The discharge valve is located in this false head and the suction valve in the piston. cooling is provided for by an open water jacket of the overflow type. The compressor is lubricated by means of a hand force feed lubricator and the engine by an hydrostatic lubricator. Smooth running is insured by two 3'-0" flywheels having 5" faces.

CONDENSERS.

In order that the engine may be run condensing a Wheeler surface condenser is provided. This is placed in a pit directly below

the engine. It contains 41 tubes in the first pass and 53 in the second, both being 5/8" outside diameter and 47 1/8" long. This gives 60.4 square feet of steam surface and 48.3 square feet of water surface. Connected to this condenser is a 4 x 6 x 6 Marsh vacuum pump.

The ammonia condenser of the double tube type consists of one bank of 1¼" pipes inside of 2" pipes, 3 pipes high and 18 feet long. This condenser is placed upon brackets along the north wall. A gallery along the same wall gives access to this as well as to the expansion coils.

STEAM PIPING.

A 2½" steam header leads from the boiler to the north wall terminating in a tee. About halfway between the boiler and the wall a 2" lead takes steam to the engine. Just above the throttle valve this is bushed to 1¼". The brine circulating pump takes steam through a 1" pipe from one branch of the tee in the end of the main header. From the other branch a 1½" pipes runs to the east wall where it is bushed to 1" and leads to the injector. The drawing of the steam piping shown later will make this clear.

EXHAUST PIPING.

The engine exhaust pipe is $1\frac{1}{2}$" and the brine pump $1\frac{1}{2}$". Both lead to a 2" exhaust header which either exhausts to the atmosphere or can be by passed through the condenser. The Marsh pump exhaust is $\frac{3}{4}$" and also leads to the exhaust header.

AMMONIA PIPING.

All the ammonia piping is $1\frac{1}{4}$" extra heavy for the gas and $\frac{1}{2}$" extra heavy for the liquid except in a few places where thermometer cups are inserted in the liquid lines. In these places it is either $\frac{3}{4}$" or 1". The ammonia gas is discharged through an oil separator into the double pipe condenser where it is liquified. The liquid then goes to the rwo receivers, which are mounted on platform scales so that the weight of ammonia used can be determined. From the receivers the ammonia is forced to the double pipe expansion coils or to the expansion coils in the freezing tank. From the expansion coils the gas is drawn back to the machine, and the cycle is then repeated. There is also an ac-

cumulator in the line but the piping is so arranged that it does not have to be used unless so desired. The drawing of the ammonia piping shows the arrangement of all by passes,etc.

BRINE SYSTEM.

Provision is made for freezing ice either by expanding the ammonia in the coils in the freezing tank or by circulating brine which has been cooled by the double pipe expansion coils which are placed on the gallery. The expansion coils on the galery consist of one bank of 1½" pipes inside of 2" pipes, 6 pipes high and 12 feet long.

The brine is circulated by means of a 5¼ x 3½ x 5 Worthington duplex pump. When ice is made by the latter method stated above the brine is pumped from the freezing tank through the double pipe cooler and into the weighing tanks and from there it gravitates back to the freezing tank. By this method the brine can be weighed.

FREEZING TANK.

The freezing tank 14'-0" long, 5'-3" wide and 3'-6" deep. It is made of sheet steel riveted together and reinforced around the top with angle irons. It is insulated from the concrete pit in which it is placed by 6" of cork felt on all sides and the bottom. In the tank are 6 banks of $1\frac{1}{4}$" pipes 8 pipes high connected to a 4" gas header at the top and a 4" liquid header at the bottom. This tank holds 35 cans 8 x 16 x 32 each can having a capacity of 100 pounds of ice. When the ice is frozen by the direct expansion of the ammonia in the coils in this tank the pump then merely furnishes circulation of the brine in the tank itself.

WATER PIPING and SUPPLY.

The water is brought into the building at the west end through a $\frac{3}{4}$" line. From there a $1\frac{1}{2}$" line runs to the point where the water branches to go to the ammonia and steam condensers, at which point a $1\frac{1}{4}$" line goes to each. In the ordinary operation the water first passes over ammonia and then over the steam condenser and back

to the weighing tank and then to the sewer. The water can be by passed to the steam condenser without running through the ammonia condenseror vici verse. The feed water for the boiler is taken from part of the circulating water.after it has passed through the condensers.

PRELIMINARY TEST.

Steam pressure was first gotten up on May 13, 1913 and the system was put under an air pressure of 190 pounds per square inch. In this way the larger leaks were found and remedied. This pressure was allowed to remain on the system over night. The gauges showed a drop in pressure by the following morning which indicated more leaks. After steam had been gotten up on the next day a pressure was then applied and most of these leaks fixed. In the afternoon of this same day, May 14, 1913, the system was given a little charge of ammonia and the leaks detected with sulphur sticks. These leaks were mostly around the stuffing boxes of the valves

and around some of the flanges. On the next day May 15, 1913, the system was charged with 100 pounds of ammonia under a pressure of about 100 pounds per square inch. This was allowed to stand over night. No leaks being apparent in the morning the remaining 150 pounds was put into the system. This was on Friday, May 16, 1913.

FINAL TEST.

On Monday, May 19, 1913, steam was gotten up and the compressor started. No readings were taken however until Wednesday, May 21, 1913, because it was necessary to let the system get into running condition. Before starting up on Monday the ice cans had been filled and on Tuesday afternoon as most of the cans were frozen by that time they were pulled every hour and refilled. This was carried out in rotation and by the time all of the cans had been pulled the first one was frozen. It was then that readings were first taken. During this time of waiting every thing was gotten ready to make the run. The run started at 7:00 P. M. on Wednesday, May 21, 1913, and ended on Friday, May 23, 1913, at 7:00 P. M.

This covered a period of 48 hours. The readings were taken every half hour and also indicator cards from each cylinder. The coal was weighed out as needed as also was the ashes. Below are listed the readings that were taken:

Ammonia Suction pressure

Ammonia discharge pressure

Boiler pressure

Steam pressure at engine

Temperature in calorimeter at boiler

Temperature in calorimeter at engine

Temperature of gas entering the compressor

Temperature of gas leaving the compressor

Temperature of gas entering condenser

Temperature of liquid leaving the cond.

Temperature of gas leaving coils in tank

Temperature of brine

Temperature water entering condenser

Temperature of water leaving condenser

Temperature of feed water

Temperature of room

The weight of condensing and feed water for the entire run.

A can of ice was pulled every hour, three quarters of an hour and every half hour, depending on the number of cans that were frozen ahead of the one that was being pulled. The log sheet shows the time at which the pulling took place as well as all data taken during the test. The coal used for the test was a mixture of hard and soft coal. The following pages give, in tabulated form, the areas and lengths of the indicator cards taken and following that is a table of the average results of the test and also of the calculated results. A sample calculation will be found in the appendix.

AREAS AND LENGTH OF CARDS

	Steam Cyl. Area			Ammonia Cyl.	
Time.	H. E.	C. E.	Length.	Area.	Length.
P.M.					
7:00	2.82	2.63	2.98	----	3.3
7:30	2.77	2.53	"	----	"
8:00	2.74	2.65	"	----	"
8:30	2.62	2.60	"	----	"
9:00	2.59	2.50	"	----	"
9:30	----	----	"	----	"
10:00	2.69	2.63	"	----	"
10:30	2.68	2.55	"	1.06	"
11:00	2.65	2.63	"	1.00	"
11:30	----	----	"	----	"
12:00	2.66	2.60	"	1.09	"
12:30	2.80	2.68	"	1.18	"
1:00	2.70	2.62	"	.90	"
1:30	2.78	2.63	"	.98	"
2:00	----	----	"	.84	"
2:30	----	----	"	.96	"
3:00	2.57	2.45	"	.93	"
3:30	2.55	2.40	"	.92	"
4:00	2.52	2.37	"	.87	"
4:30	----	----	"	1.00	"

Time. A.M.	Steam Cyl. Area H. E.	C. E.	Length.	Ammonia Cyl. Area.	Length.
5:00	2.50	2.49	2.98	.89	3.3
5:30	----	----	"	.89	"
6:00	2.58	2.55	"	.88	"
6:30	2.70	2.66	"	.94	"
7:00	----	----	"	.87	"
7:30	----	----	"	.90	"
8:00	----	----	"	-----	"
8:30	2.88	2.77	"	.96	"
9:00	----	----	"	----	"
9:30	----	----	"	.92	"
10:00	----	----	"	.92	"
10:30	----	----	"	.87	"
11:00n	2.85	2.67	"	.94	"
11:30	----	----	"	.93	"
12:00	2.48	2.53	"	.98	"
12:30	----	----	"	----	"
1:00	2.88	2.76	"	.98	"
1:30	----	----	"	1.04	"
2:00	2.72	2.62	"	1.06	"
2:30	----	----	"	1.04	"

	Steam Cyl. Area			Ammonia Cyl.	
Time. P.M.	H. E.	C. E.	Length.	Area.	Length.
3:00n	2.61	2.47	2.98	1.03	3.3
3:30	2.48	2.40	"	1.14	"
4:00	----	----	"	1.03	"
4:30	----	----	"	1.11	"
5:00	2.88	2.70	"	~~1~~.96	"
5:30	----	----	"	.99	"
6:00	3.05	2.39	"	.82	"
6:30	-----	----	"	----	"
7:00	2.82	2.63	"	----	"
7:30	----	----	"	.77	"
8:00	2.79	2.70	"	.85	"
8:30	----	----	"	.88	"
9:00	2.75	2.57	"	.86	"
9:30	----	----	"	.78	"
10:00	2.82	2.67	"	.82	"
10:30	-----	----	"	.79	"
11:00	2.90	2.80	"	.67	"
11:30	----	----	"	.66	"
12:00	2.83	2.76	"	.76	"
12:30	----	----	"	.61	"

Time. A.M.	Steam Cyl. Area H. E.	C. E.	Length.	Ammonia Cyl. Area.	Length.
1:00	2.90	2.76	2.98	.74	3.3
1:30	----	----	"	.73	"
2:00	----	----	"	.80	"
2:30	----	----	"	.79	"
3:00	2.55	2.35	"	.37	"
3:30	2.60	2.47	"	.82	"
4:00	2.49	2.38	"	.86	"
4:30	----	----	"	.88	"
5:00	2.62	2.52	"	.87	"
5:30	----	----	"	.80	"
6:00	----	----	"	.96	"
6:30	2.73	2.64	"	----	"
7:00	2.85	2.67	"	----	"
7:30	2.37	2.83	"	.98	"
8:00	2.92	2.87	"	.96	"
8:30	----	----	"	1.05	"
9:00	3.13	3.02	"	1.10	"
9:30	----	----	"	1.01	"
10:00	2.95	2.76	"	.87	"
10:30	----	----	"	.87	"

Time. A.M.	Steam Cyl. Area H. E.	C. E.	Length.	Ammonia Cyl. Area.	Length.
11:00	2.90	2.76	2.98	1.10	3.3
11:30	----	----	"	1.07	"
12:00	2.33	2.65	"	1.17	"
12:30	----	----	"	1.06	"
1:00	----	----	"	1.05	"
1:30	2.98	2.76	"	1.13	"
2:00	----	----	"	.97	"
2:30	----	----	"	----	"
3:00	----	----	"	.92	"
3:30	----	----	"	.92	"
4:00	----	----	"	.95	"
4:30	----	----	"	1.06	"
Average.	2.744	2.63	2.98	.916	3.30

Note:-

All spaces left blank are due to the cards being too faint to integrate or not taken.

AVERAGE RESULTS.

Time of run in hours	48
Speed, R. P. M.	137.7
Boiler pressure	83.5
Steam pressure at engine	53.1
Ammonia discharge pressure	121.2
Ammonia suction pressure	18.7
Room temperature	66.1
Feed water temperature	68.5
Temperature in calorimeter at boiler	217.0
Temperature in calorimeter at engine	219.0
Temp. gas entering NH_3 condenser	111.8
Temp. liquid leaving NH_3 Condenser	55.0
Temp. cooling water entering condenser	51.8
Temp. cooling water leaving condenser	62.5
Temp. gas entering compressor	60.0
Temp. gas leaving compressor	145.5
Temperature of brine leaving tank	5.0
Temperature of gas leaving coils in tank	3.4

AVERAGE RESULTS (continued)

Barometer	29.306
Weight of coal, total,	3971
Weight of ash, total,	586
Weight of feed water, total,	17594
Weight of cooling water, total,	203798
Weight of ice, total,	6670.5

Note:-

The barometer readings were obtained from the weather bureau.

CALCULATED RESULTS.

I. H. P. Steam cylinder head end	2.17
I. H. P. Steam cylinder crank end	2.09
Total I. H. P. Steam cylinder	4.26
Total I. H. P. Ammonia cylinder	1.64
Ratio of ammonia to steam I. H. P.	.385
Quality of steam at boiler, % ,	96.2
Quality of steam at engine, %,	97.2
Apparent evaporation per pound of coal	4.43
Factor of evaporation	1.15
Equivalent evaporation	5.094
Boiler H. P.	30
Boiler and grate efficiency, %,	41.25
Pounds of coal per 24 hours	1985.5
Tons of ice per 24 hours	1.668
Tons of ice per hour	.0695
Tons of ice per ton of coal	1.68
Tons of ice per I.H.P. hour of NH_3 Cyl.	.0424
Tons of ice per I.H.P. hour of steam cyl.	.0163
Tons of ice per boiler H.P. hour	.0023

DISCUSSION.

On the whole this test has been a marked success as far as expectations were concerned. Very little trouble appeared throughout the preliminary or final tests and although every part of the plant did not operate in the most efficient way, the results were reasonable and fairly good.

The boiler and grate efficiency of 41.25% is fair for an ordinary return tubular boiler with hand firing. Part of the time soft coal was used and this was very satisfactory. Near the end of the test hard coal was tried but this was not as satisfactory so a mixture of half and half was tried and this was found to work better. With this mixture it was much easier to keep up the steam pressure.

The apparent evaporation of 4.43# ~~water~~ per pound of coal is somewhat low for economical running but this was to be expected of the boiler used.

The ratio of the I.H.P. of the ammonia cylinder to that of the steam cylinder - or as we might say the mechanical efficiency of the engine and compressor - is very low being only

38.5%. The cards of the steam cylinder show fairly good steam action in the cylinders but those of the compressor indicate that the valves did not operate as they should. On page 30 is shown an example of an ideal card which should be approached as near as possible. The average card is shown on page 31. This card shows a marked departure from the ideal. This is what causes the above efficiency to be so low.

The fact that the quality of the steam at the boiler is lower than that at the engine would seem to show that there was a separating effect in the line instead of a condensation effect, or else an unknown error has come into play. It may be that the steam was too wet to get accurate results from a throttling calorimeter.

APPENDIX.

SAMPLE CALCULATIONS.

Indicated Horse Power:

Steam Cyl. Head End.

$$M.E.P. = \frac{2.744 \times 40}{2.98} = 36.85 \ \#/ \ sq. \ in.$$

$$I.H.P. = \frac{P.L.A.N.}{33000} = \frac{36.85 \times 28.27 \times 137.7}{2 \times 33000}$$

$$= 2.17 \ I.H.P.$$

Crank end.

$$M.E.P. = \frac{2.63 \times 40}{2.98} = 35.33 \ \#/ \ sq.in.$$

$$I.H.P. = \frac{p \ l \ a \ n}{33000} = \frac{35.33 \times 1 \times 28.27 \times 137.7}{2 \times 33000}$$

$$= 2.09 \ I.H.P.$$

Total I.H.P. = 4.26.

Ammonia cylinder.

$$M.E.P. = \frac{.916 \times 100}{3.30} = 27.8 \ \#/ \ sq.in.$$

$$I.H.P. = \frac{P \ L \ A \ N}{33000} = \frac{27.8 \times 1 \times 28.27 \times 137.7}{2 \times 33000}$$

$$= 1.64 \ I.H.P.$$

Ratio between I.H.P. of ammonia and steam

$$\text{cylinders} = \frac{1.64}{4.26} = .385.$$

Quality of steam at boiler = 96.2% (Mollier Diagram)

Quality of steam at engine = 97.2% (" ")

Boiler calculations.

Apparent evaporation per pound of coal

$$\text{as fired} = \frac{17594}{3971} = 4.43\#$$

$$\text{Factor of evaporation} = \frac{xr \quad q - (t - 32)}{970.4}$$

$$= \frac{1153 - 68.5 \quad 32}{970.4} = \frac{1116.5}{970.4} = 1.15.$$

Equivalent evaporation per pound of coal

as fired = 4.43 x 1.15 = 5.0945#

Heat absorbed by boiler per pound of coal

as fired = 970.4 x 5.0945 = 4950 B.t.u.

Assuming 12000 B.t.u. per pound as the calorific

value of coal as fired

$$\text{Boiler and grate efficiency} = \frac{4950 \times 100}{12000 \quad x} = 41.25\%$$

$$\text{Boiler Horse Power} = \frac{34.5}{1.15} = 30 \text{ Boiler H.P.}$$

$$\text{Tons of ice per ton of coal} = \frac{6670.5}{3971} = 1.68.$$

Tons of ice per I.H.P.hr. of ammonia cyl.

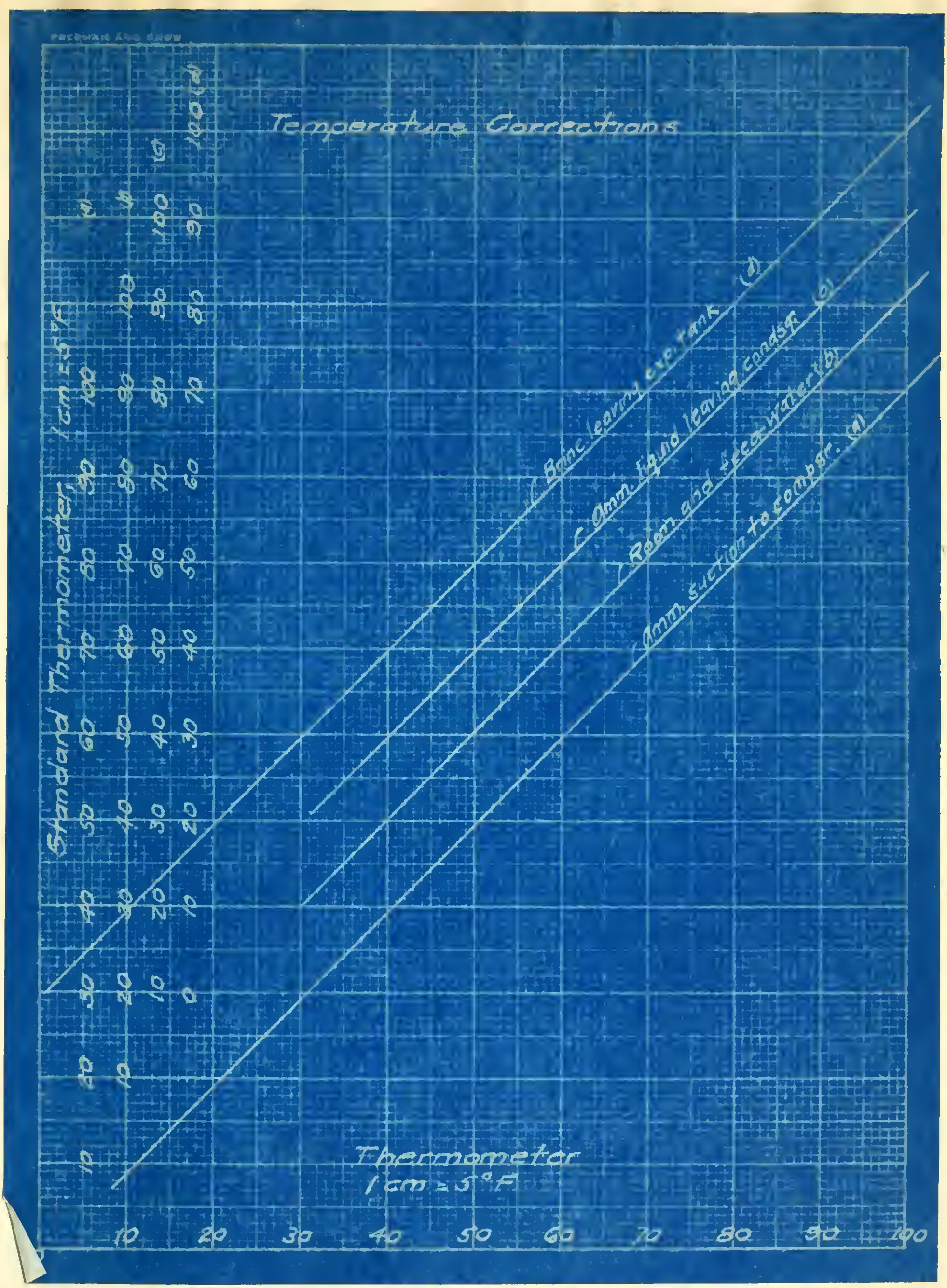
$$= \frac{.0695}{1.64} = .0424.$$

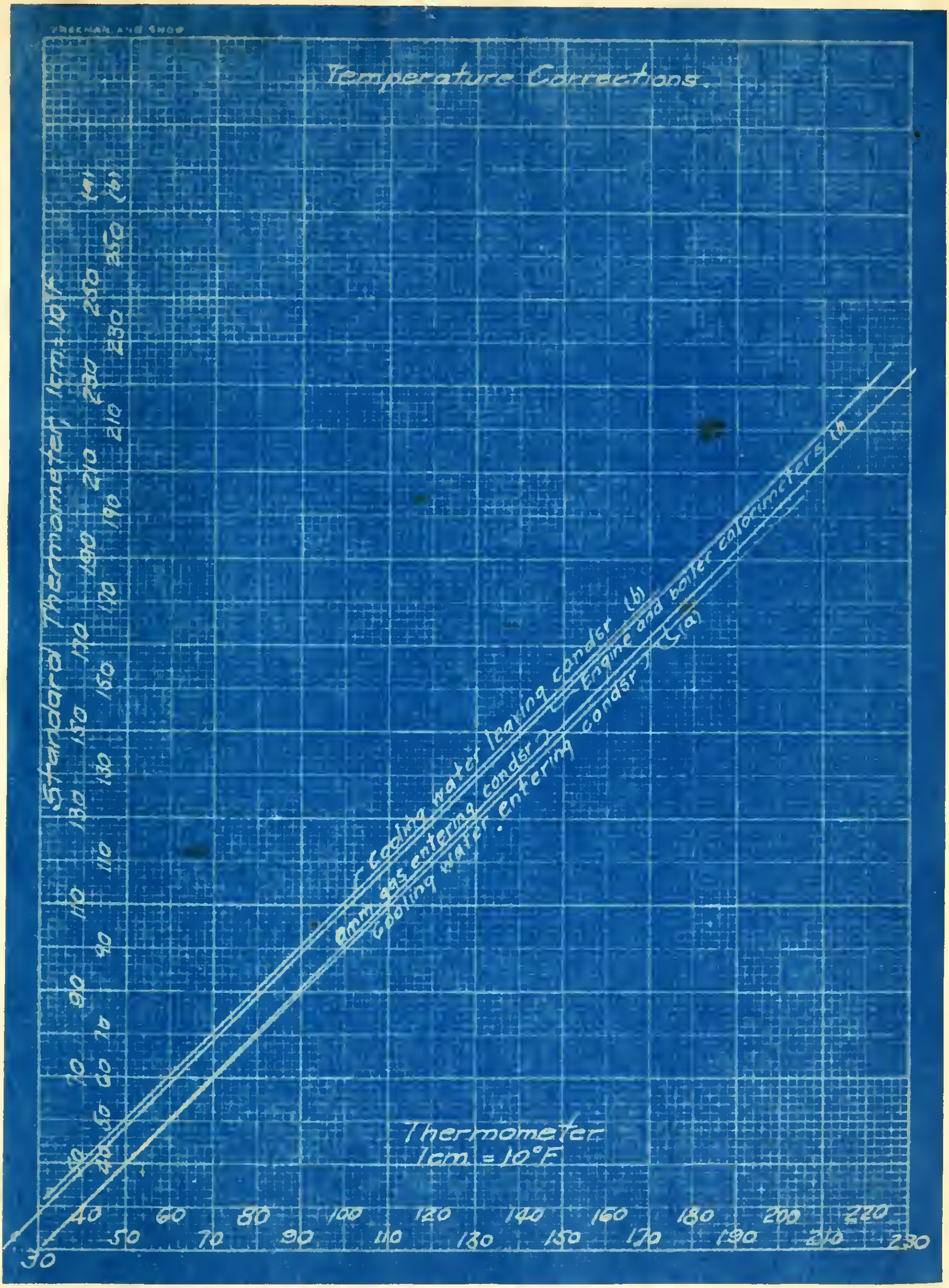
Tons of ice per I.H.P. hr. of steam cylinder

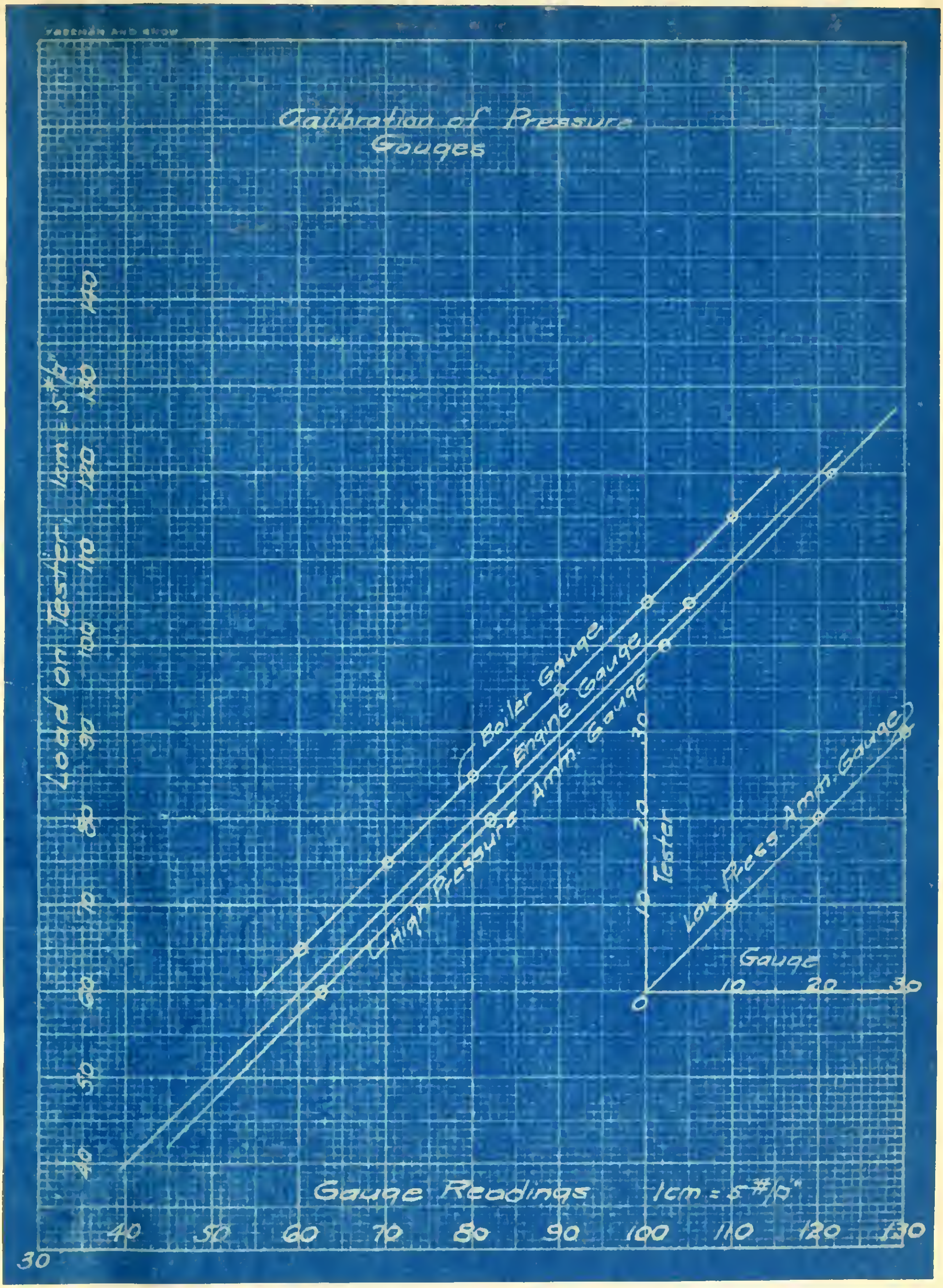
$$= \frac{.6005}{4.26} = .0163$$

Tons of ice per boiler H.P. hr.

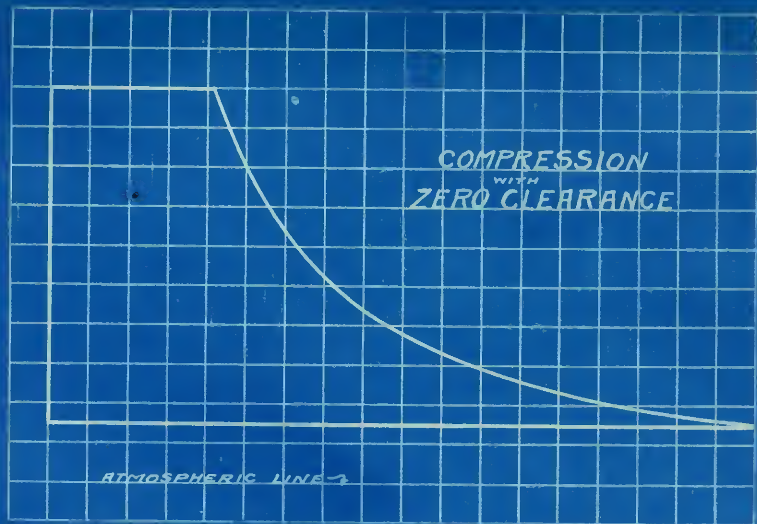
$$= \frac{.0695}{30} = .0023.$$


Temperature Corrections
Standard Thermometer, 1 cm = 5° F
Brine leaving evap. tank (d)
Amm. liquid leaving condsr. (c)
Room and sea water (b)
Amm. suction to compsr. (a)
Thermometer
1 cm = 5° F
10
20
30
40
50
60
70
80
90
100


Temperature Corrections.
Standard Thermometer 1cm = 10°F
30 40 50 60 70 80 90 110 130 150 170 190 210 230 250 (a)
130 150 170 190 210 230 250 350 (b)
Cooling water leaving condsr (b)
Amm. gas entering condsr
Engine and boiler calorimeters (a)
Cooling water entering condsr (a)
Thermometer
1cm = 10°F
40 60 80 100 120 140 160 180 200 220
30 50 70 90 110 130 150 170 190 210 230



Calibration of Pressure Gauges
Load on Tester, 1cm = 5#/□"
40
50
60
70
80
90
100
110
120
130
140
Boiler Gauge
Engine Gauge
High Pressure Amm. Gauge
Low Press Amm. Gauge
Tester
10
20
30
Gauge
0
10
20
30
Gauge Readings 1cm = 5#/□"
30
40
50
60
70
80
90
100
110
120
130



IDEAL AMMONIA CARD

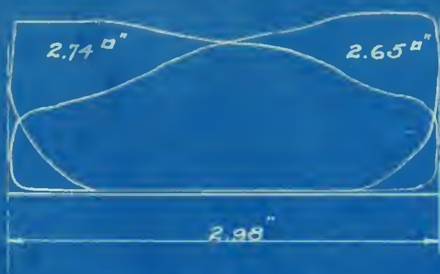
COPY FROM BULLETIN #32

YORK MFG. CO.

JULY - 1908

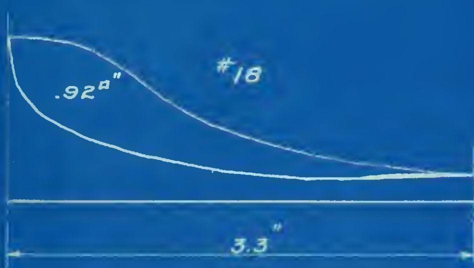
Average Cards

#8



STEAM CYL.

M.E.P.	H.E. =	36.85
	C.E. =	35.33
I.H.P.	H.E. =	2.17
	C.E. =	2.09
TOTAL I.H.P.	=	4.26



AMMONIA CYL.

M.E.P. = 27.8

I.H.P. = 1.64

LOG SHEET #1.

May 21, 22, + 23, - 1913

Direct Compression through Accumulator. Engine Noncondensing.

#1

1.

May 21, 1913 - 7:00 P.M.

May 23, 1913 - 7:00 P.M.

																								Time of Pulling Ice
P.M.																								P.M.
7:00	144	29.18	75	50	130	21				211		55.5	52	61			165	12					106	7:00
7:30	140		90	52	130	21	72	68		210		56	52	64.5	7	62	166	10						
8:00	140		90	53	130	20	73	69		210	122	55.5	52	60.5	7	62		9					106	8:00
8:30	142		90	50	125	20	74	71		210	121	56	52	60.5	7	62	152	9						
9:00	141		85	46	125	20	72	70		210	119	55.5	52	62	6	61	154	8					109	9:00
9:30	142		90	46	125	20	70.5	72		210	119	55	52	60	6	60	154	8						
10:00	140		87.5	48	125	20	71	69.5	210	212	119	56	52.5	62	5.25	60	153	9					106	10:00
10:30	135		90	45	124	20	70	68	210	212		55	52	60	5	60	154	8						
11:00	137		75	52	124	20	69	71		212	115	55.5	52	61	5	60		8.5					106	11:00
11:30												55.5			5	60								
AM 12:00	133		90	47	122	20	69	67	210			55.5	52	59			150	7					106	AM 12:00
12:30	136		90	47	121	20	66	67		210	114	55.5	52	60	4.5	60		7						
1:00	133		85	47	124	20	65.5	66	210			55.5	52	61	4	60	147	7	124	40	1709	1578	107	1:00
1:30	148		69	49	122	20	65.5	66		210	111	55.5	52	59	4	60		6.5						
2:00	133		95	48	125	19	62.5	67	210			55.5	52	62.5	4	57.5	145	6.5					106	2:00
2:30	139		80	47	123	20	66.6	69		212	111.5	55.5	52	60	3.5	59.5		6						
3:00	136		72	48	124	19	70.0	67	210			55.5	52	62	3.5	57.5	145	6		45			104	3:00
3:30	139		83	49	123	20	66	66.5		212	111	55.5	52	59.5	3	60		5.5						
4:00	136		75	49	123	19	66.5	66	210			55.5	52	61.5	3	60	143.5	5	200				105	4:00
4:30	131		80	49	120	18	67.5	66.5		210	110	55.5	52	59	2.5	60		5						
5:00	132		60	47	120	17	67	66.5	208			55.5	52	61	2.5	60	140	5					113	5:00
5:30	138		80	49	120	17	65	67		212	109	55.5	52	60	2.5	60		5		26.5				
6:00	138		86	50	122	18	67	66.5	210			55.5	52	61.5	2	60	142.5	4.5	210				108	6:00
6:30	138		86	52	120	19	66.5	66.5		212	107	55.5	52	60	2	60		4				25737		
7:00	140	29.20	73	53	124	18	67	68	210	214		55.5	52.5	64	1.5	60	145	4.5			2617	26304	106	7:00
7:30	135		88	53	122	17	68	70	210	214	110	55.5	52.5	61	1.5	60		3.5				2618		
8:00	140		95	55	124	18	66		210	212		56	52.5	64	1	60	144.5	3					110.5	8:00
8:30	138		80	54	120	18	64.5	66	210	212	110	56	52.5	61	1.5	60		3	600					
9:00	142		94	56	124	17	65.5	68	210	211		58	52.5	63	1.5	60	145	3					107.5	9:00
9:30	139		85	56	123	17	66	70	208	214	110	56	52.5	61	1.5	62		3						
10:00	144		85	55	125	16	65.5	68	210	215		56	52.5	65	1.5	60	146	3		46.5			105.5	9:45
10:30			65	54	124	16	69	71	209	215	110	55.5	52	65		60.5		5						
11:00	137		77	54	122	16	65	65	210	214		56	52	60.5		60	145	3.5					106	10:30
11:30	136		82	54	124	16	61	67	208	216	111	55.5	52	63.5		60	147	4						
PM 12:00	135		76	54	124	17	67	70	209	214	111	55.5	52	63.5		60	143	3.5					105.5	11:15
12:30	133		67	54	121	17	68	69.5	209	212	111	56	52	60		60	148	4					106	P.M. 12:00
1:00	129		56	55	122	17	69.5	75.5	208	210	111	55.5	52	60		60	147	4					108	12:45
1:30	135		67	55	124	17	69.5	73	208	211	110	55.5	52	63		60	145	4.5					104.5	1:30
2:00	134		76	58	120	17	66	69.5	208	212	111	56	52	61		60	148	4					104.5	2:15
2:30	138		79	54	124	16	67.5	69.5	208	212	112	56	52	64		60	147	3.5	30				99.5	3:00
3:00	135		68	53	123	17	66.5	69.5	208	212	113	56	52	63.5		60	150	3.5					105.5	3:45
3:30	125		50	58	120	17	70.5	69.5	208	210	112	56	52	57.5		61	146	3.5					107	4:30
4:00																				39.6			107	5:15
4:30																								
5:00	142		95	55	123	18		69.5	208	209	110	56	52	60		60	152	5.5	67.5					

LOG SHEET #2

#2

1.

																					P.M.
P.M. 5:30	139		77	56	126	17	67	70	208	208	112	56	52	65	60	146	6			106.5	6:00
6:00	138		73	56	124	18		72	208	209	111.5	56	52	61	60	143	5			105.5	6:45
6:30	132		73	54	125	17	66	67	206	207	112	56	52	61	60	142	6			105.6	7:30
7:00	139	29.31	69	54	125	17		69	208	208	111	56	56	61.5	61	141	6			104	8:15
7:30	135		83	52	126	17	67	68	209	208	110	56	52	63	60	141	6		25.5	104	9:00
8:00	137		80	50	127	18		70	206	208	110	55	52	61	59	139	6			106.5	9:45
8:30	140		80	50	123	18	70	69	206	210	110	55.5	52	63	59.5	141	6			106	10:30
9:00	137		78	50	120	18		68.5	208	210	107	55.5	52	60	59	140	6			107.5	11:00
9:30	134		68	48	120	17	69	77	208	210	108	55.5	52	60	58.6	139.5	6	100		105	11:30
10:00	139		72	50	121	18		74	208	208	107	55.5	52	63	58	139	6			106.5	A.M. 12:00
10:30	137		78	58	120	17	64	70.5	208	210	108	55	52	60	58	141	6	100		[illegible]	12:30
11:00	141		87	53	121	18		70.5	208	210	109	55	52	60	58	142	6			105	1:00
11:30	140		75	55	120.5	18	65	66	206	208	109	55	52	60	59	142	6	100			
A.M. 12:00	141		80	60	120	17		67	208	210	109	55.5	52	60	60	141	6				
12:30	134		63	50	120	17	66	70	208	206	107	55.5	52	59.5	60	135	6				
1:00	136		70	65	120	17		68.5	206	206	107	55	52	59.5	60	140	6	200			
1:30	138		80	65	120	17	66	69.5	210	210	107	55	52	59.5	60	140	7			106	1:30
2:00	140		82	60	121	19		67	206	207	108	55.5	52	60	60	141	6.5			104.5	2:00
2:30	140		73	70	120	19	67	71	208	208	108	55.5	52	60	60	143	6.5			105.5	2:45
3:00	136		70	50	120	19		71	206	207	110	55	52	62.5	60	142	7			106	3:30
3:30	134		75	55	120	19	68	73.5	206	210	110	55	52	59.5	60	142	6.5			104	4:15
4:00	136		65	49	120	19		66.5	205	208	108	55	52	59	59.5	141	7		82	104.5	5:00
4:30	135		75	50	120	19	65	70.5	208	208	108	55	52	62.0	59	142	7			105	5:45
5:00	137		96	58	121	19		71	206	208	107	55	52	62.0	60	143	7			106	6:30
5:30	140		85	75	120	20	62	68	206	208	110	55.5	52	60	60	143	7			107	7:15
6:00	134		77	55	120	19		72	206	208	110	55.5	52	63	60	143	7			106	8:00
6:30	141		95	55	123	19	64	68	206	[illegible]	110	55	52	64	60	143	7			107.5	8:45
7:00	140	29.36	83	50	122	19		66	204	[illegible]	110	55	52	60.5	60	143	7		40	108	9:30
7:30	135		85	54	123	19	65	67	204	208	111	55	52	64	60	143	7			106	10:15
8:00	136		80	56	124	19		67.5	206	205	110.5	55	52	64	59.6	143	7			105	11:00
8:30	142		77	67	122	19	66	64	204	206	110	55	52	60.5	60	142	7	176	60.5	106.5	11:45
9:00	137		91	58	125	19		67.5	205	208	110	55	52	62	60	147	7	[illegible]		106.5	A.M. 12:30
9:30	138		90	54	124	19	61	69.0	204	206	109	55	52	65	60	143	6.5	122		105.5	1:15
10:00	144		92	54	122	19			204	206	110	55	52	61	60	143	7		42	[illegible]	2:00
10:30	142		87	54	125	19	60	67	206	208	110	55	52	64.5	59.5	142	6.5				
11:00	140		87	54	125	19		68	204	205	109	55	52	66	60	146	7				
11:30	133		71	55	123	20	61	67	204	204	110	55	52	60.5	60	143	7.5				
P.M. 12:00	142		91	53	121	20		68	204	204	110	55	52	61	60	143	7				
12:30	143		83	54	125	20	62	72.5	204	204	111	55	52	64	61.5	144	7				
1:00	138		71	54	123	20			204	204	111	55.5	52	60	62	141	7		33		
1:30	138		73	55	123	20	63	66.5	203	204	110	55.5	52	64	61	142	6.5				
2:00	131		76	54	121	20			203	204	110	55.5	52	60	61	143	6.5				

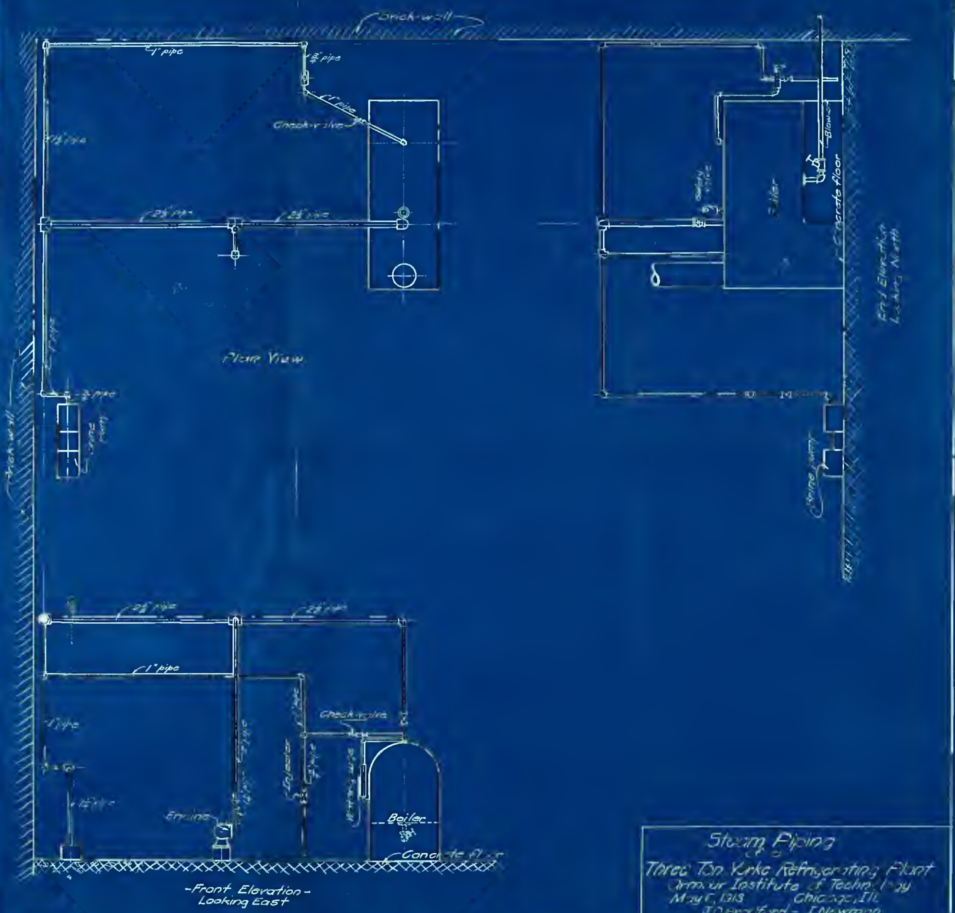
LOG SHEET #3

#3

1.

																								Time in P.M.
2:30	188		67	54	123	20	65	64.5	204	203	110	56	51.5	60		60.5	141.5	6.5	121	5186		5086	105.5	2:45
3:00	186		61	54	123	20	69	65.5	204	206	109	55	51.5	60		60.5	140	7		6181		2181	103	3:30
3:30	182		64	54	124	20	65		204	205	109	55	51.5	62.5		60.5	142	7				27087	106.5	4:15
4:00	140		86	54	121	20	61	70.5	204	204	110	56	51.5	60.5		61	141.5	7	130			31162	104.5	5:00
4:30	137		68	54	121	20	70	65.5	204	202	110	55	51.5	61		60	143	7	133			7916	107	5:45
5:00	135		65	54	123	20	66	70	204	202	110	55	51.5	63		60.5	142	7.5				26964	105.5	6:30
5:30	130		59	54	124	20	69	67	202	202	109	55	51.5	59.5		61	139	7.5				6097	105	7:00
6:00	136		52	54	121	20	67	70	202	202	108	55	51.5	60.5		60	139	7.5		74		34128		
6:30	134		49	51	124	20	66	67	202	202	109	55	51.5	62		60	138	8	67.5					
7:00	135	2740	50	50	124	20	66	67	202	202	108	55	51.5	61		60	138	8		22				
Grand AVERAGE	137.7	27.306	78.8	53.1	123.9	18.65	65.3	67.8	206.5	205.6	110.5	55.1	51.8	61.4	3.36	60	144	5.77	3371	586	17594	203748	106	
Grand Average Corrected	137.7	27.306	68.5	53.1	121.2	18.7	66.1	68.5	217	214	111.5	55	51.9	61.5	3.38	60	146.5	[illegible]	3471	586	17594	203748	106	
Grand Sum	12793		7412	5003	10381	1758	5942	6021	16534	18154	1133	5184	4.771	5911	98	5644	11663	542	3471	586	17594	203748	16706½	
Grand No. Items	93		94	94	94	94	92	89	80	87	74	84	94	94	29	94	81	94					63	

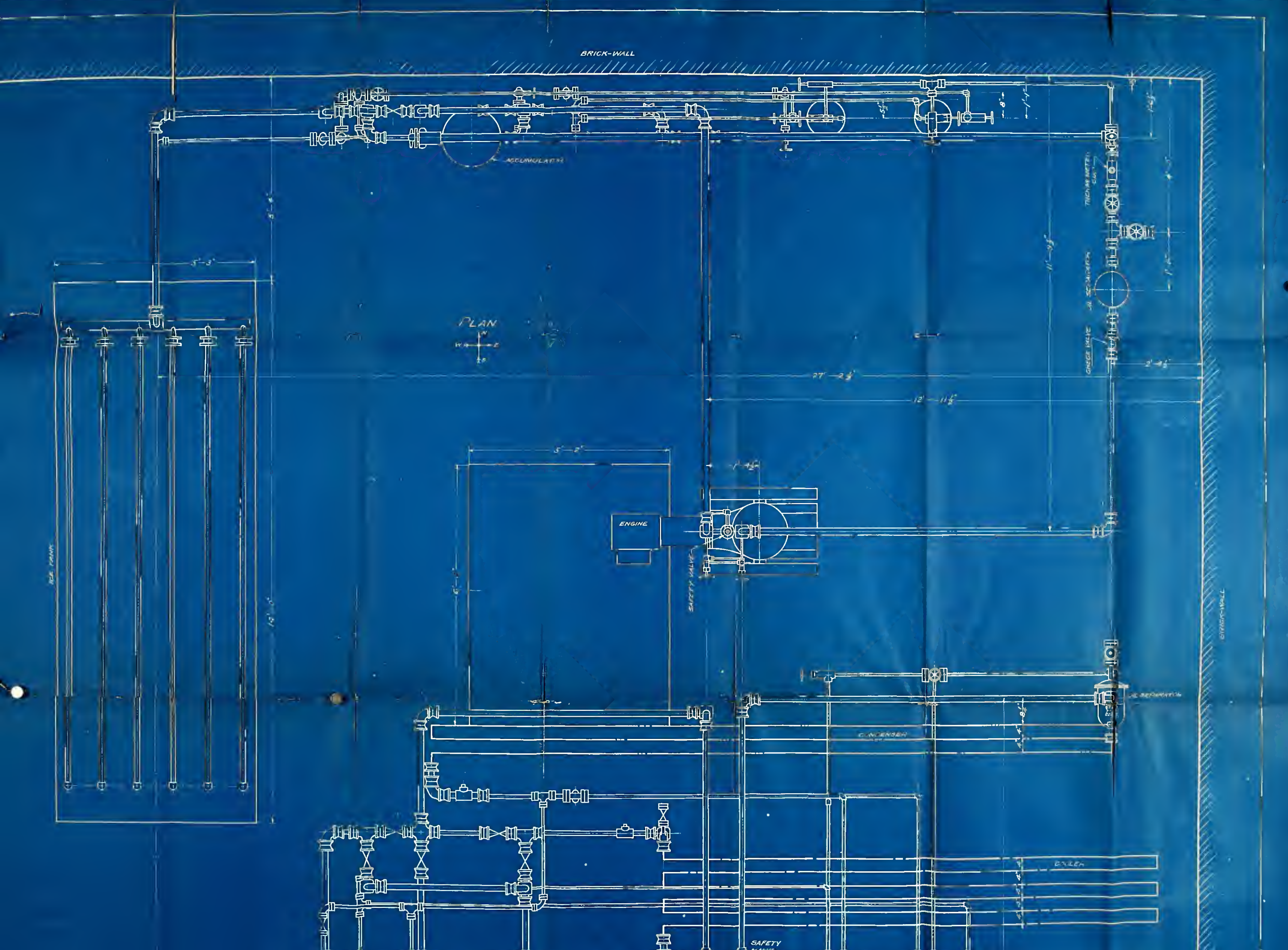
STEAM PIPING



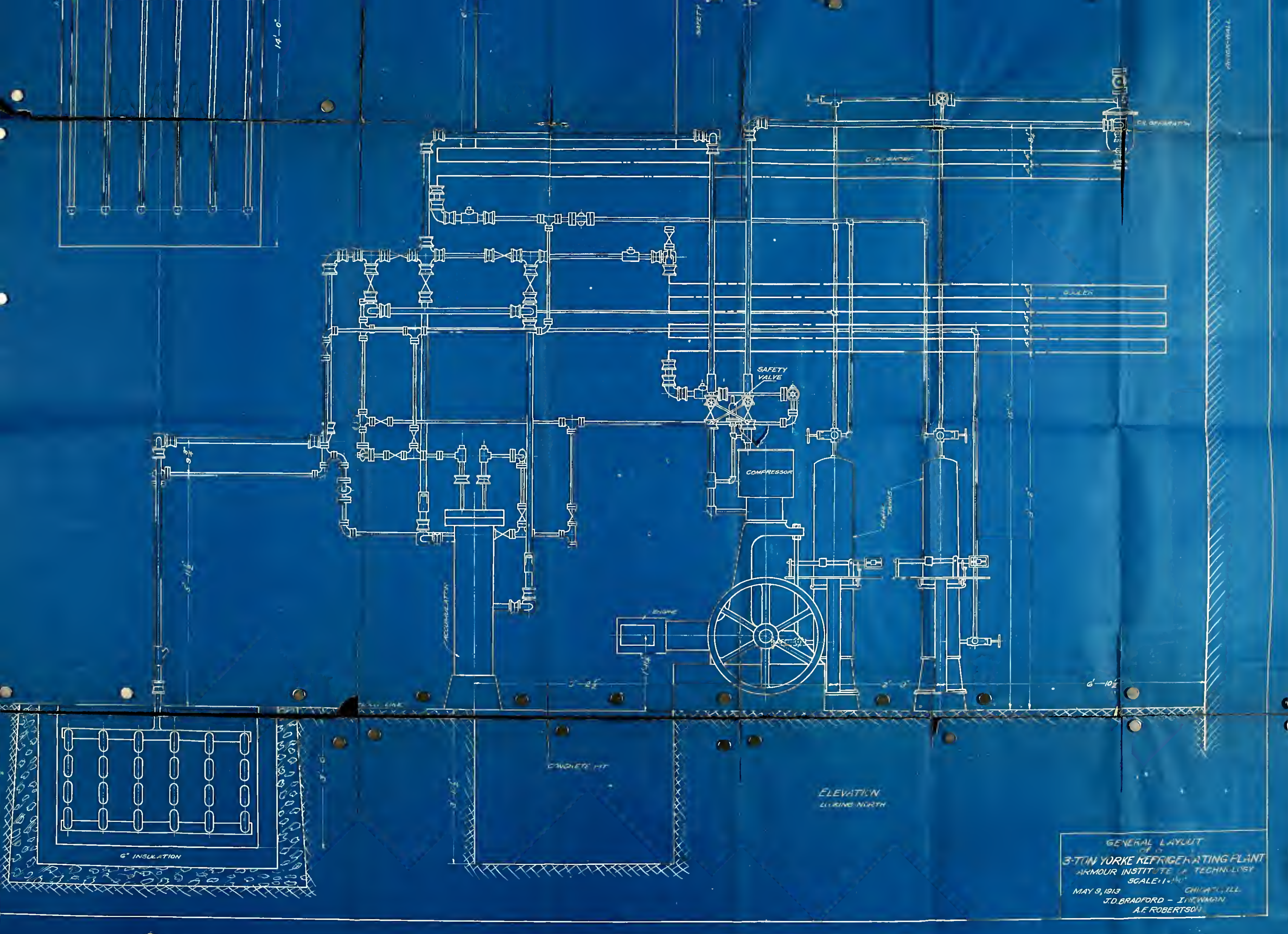
Steam Piping

Three Ton Yorke Refrigerating Plant
Armour Institute of Technology
May 6, 1913 Chicago, Ill.
J.D. Crawford - I. Newman
A.F. Robertson

AMMONIA PIPING



BRICK-WALL
ACCUMULATOR
PLAN
ENGINE
SAFETY VALVE
CHECK VALVE
CONDENSER
ICE TANK
SAFETY



14'-0"
SAFETY
CONDENSER
BOILER
SAFETY VALVE
COMPRESSOR
ACCUMULATOR
ENGINE
3'-2½"
6'-10½"
5'-11½"
6" INSULATION
CONCRETE PIT
ELEVATION
LOOKING NORTH
GENERAL LAYOUT
3-TON YORKE REFRIGERATING PLANT
ARMOUR INSTITUTE OF TECHNOLOGY
MAY 9, 1913
CHICAGO, ILL.
J.D. BRADFORD - I. NEWMAN
A.F. ROBERTSON